SCIENCE INFORMATION NOTES

A collection of articles on scientific and technological matters, research policies, science and society, higher learning etc.

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Employment of engineers and scientists

by Philip H. Abelson

A deepening recession has brought the official national unemployment rate to about 10 per cent. In its early phases, the downturn affected mainly the construction and auto industries, their suppliers, and people who were not well prepared or especially skilled. But now the effects of recession, coupled with high interest rates, are spreading to most segments of the economy. Thus far, scientists and engineers have been relatively insulated from the decline. For example, unemployment among members of the American Chemical Society is less than 2 per cent and few, if any, major layoffs have been announced. However, the first quarter profit of the chemical industry is down 33 per cent and continuation of that trend would surely affect employment.

Prospects for employment of young scientists and engineers by industry have changed recently. Six months ago, industry was avidly, even frantically, recruiting. But the deepening recession has generated gloom and uncertainty. Pessimists have begun to remind us of the situation in the late 1960's when stories appeared in the New York Times and elsewhere about an engineer driving a taxi. These stories dramatized unemployment among engineers and contributed to a sharp drop in engineering enrollments and a later shortage of engineers.

To obtain an indication of developing attitudes and trends, I contacted personnel officers in ten major firms active in applied science and engineering. Only one of them will hire more young engineers during the current recruitment year than it did in the preceding period. Imbalances of supply and demand vary with fields. In a few specialties, such as those related to computers and their applications, positions are still unfilled. In some fields, such as construction engineering, mining engineering, and metallurgy, there are far more applicants than positions. Respondents were confident that they would be recruiting actively in the coming season. The consensus was that the top fourth of classes in chemical, electrical, and mechanical engineering will be eagerly sought. In those fields, the upper two-thirds of the graduates will probably find jobs in their profession. One of the officers said that a person in the lower third needs to show leadership qualities and be an extrovert. Then he or she will probably wind up in marketing.

The personnel officers also indicated that earlier broad patterns of job and salary offers provided by the College Placement Council are likely to continue. Engineers, who constitute about

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8 per cent of the graduating class, have received more than 60 per cent of the offers and the salaries provided exceed those in other fields. The latest compilation includes data for the period july 1981 to March 1982 and thus covers most of the recruitment for the current graduating class. The top and bottom monthly salary offers (90th and 10th percentiles) were as follows: chemical engineering, $2425 and $2100; electrical engineering, $2225 and $1834; mechanical engineering, $2350 and $1875; computer science, $2125 and $1608; and physical and earth sciences other than chemistry, $2400 and $1360. Offers were much lower in some fields. The corresponding figures for some of them were: biological sciences, $1970 and $1000; business, $1870 and $1075; and humanities $1650 and $833.

In whatever situation humans find themselves, they tend to overreact and to assume that a present state of affairs will continue indefinitely. The bleak outlook for some fields will not prevail forever, and the favourable status of engineers and physical scientists may lead to a surplus of them. However, the top fraction will be much sought after. We all know that good grades are an imperfect measure of a person's potential. But in an imperfect world, it is useful to have them, especially if they are in courses known to be demanding. The world must adjust to changed energy sources and feed-stocks and to a further development of the computer revolution. The changes will require two decades at minimum and will demand the attention of many of our most capable minds.

(Science, 216, 4551 (June11, 1982) p. 1177)

What battered the satellites of Saturn?

by Richard A. Kerr

Everywhere scientists have looked in the solar system, from innermost Mercury to the outer satellites of Saturn, there are craters. Ever since researchers decided that these craters are largely impact rather than volcanic craters, they have wondered where the impacting bodies came from. Voyager's observations at Saturn revealed two episodes of bombardment, which suggests to some that comets are behind much of the pummeling of solar system bodies.

Eugene Shoemaker of the U.S. Geological Suvey in Flagstaff argued at the Tucson meeting that objects from outside the Saturn system formed the oldest craters on the Saturnian satellites. A mammoth crater is centered or nearly centered on the leading face of both Mimas and Tethys, he notes, which is the most likely impact site for an object falling into the system. The lack of collisional debris on irregularly shaped Hyperion suggests another impact by a massive external body, Shoemaker says, because the most likely source of the high energy impactor required to disperse the debris would be outside the system.

If external objects did from the older craters, Shoemaker reasons, then the objects probably came from beyond Saturn. Only in the vicinity of Neptune and Uranus did planetesimals linger long enough after the formation of the solar system to create the observed bombardment, he says. Over the first few hundred million years, close encounters with the major planets scattered these icy bodies in all directions. Of those sent well beyond Pluto, a few still occasionally fall toward the sun as comets. Those sent inward cratered the satellites and planets of the rest of the solar system. That was the earliest bombardment of the satellites of Saturn, Shoemaker says. It was so intense that it probably shattered the smaller, inner satellites. Most reassembled themselves, he says, but some fragments produced the second cratering episode, and others appear to have persisted to the present as small companion satellites sharing the orbits of larger satellites.

Robert Strom and his colleagues at the University of Arizona are not convinced that external objects caused either of the two cratering episodes. They find no heavier cratering on the leading satellite faces than on trailing faces. That suggests to them that the impactors came from within the system, perhaps from debris left after planet formation or

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satellite disruption. They also conclude that comets cannot dominate the older cratering at both Jupiter and Saturn, as suggested by Shoemaker, because the cratering records on those two sets of satellites are different.

Shoemaker responds that the record has been altered. On the Jovian satellites, large craters have been erased by softening of the surface ice. On the inner planets, comets produced smaller craters because the sun vaporized much of their ice before they hit.

The early solar system, as seen in the cratering record, seems to be at least partly in the eye of the beholder."

(Science, 216, 4551 (June 11, 1982) p. 1211)

Health and behaviour
by David A. Hamburg

It is our good fortunue to live in a time when the nature of living organisms is rapidly being elucidated. Recent advances in molecular and cellular biology exceed what anyone could have imagined as recently as a few decades ago. They link up with other fronts, such as neurobiology and human behaviour.

Nowhere are the needs and opportunities for progress in the biobehavioral sciences clearer than in problems of health and behaviour. These matters are documented in a new report from the Institute of Medicine(IOM), National Academy of Sciences. Behavioral factors contribute to much of our burden of illness. Half of the mortality from the ten leading causes of death in the United States is strongly influenced by life-style. Known behavioral risk factors include cigarette smoking, excessive consumption of alcoholic beverages, use of illicit drugs, certain dietary habits, insufficient exercise, reckless driving, nonadherence to medication regimens, and maladaptive responses to social pressures.

One powerful stimulus to the biobehavioral sciences has been the remarkable progress of neurobiology pertinent to behaviour, recognized in the Nobel Prizes of 1977 and 1981. There is now an unprecedented array of molecules, cells, circuits, systems, techniques, and concepts available for research on problems related to behaviour and health. One crucial linkage of the biomedical and biobehavioral sciences is in the study of the final common pathway through which the brain controls the endocrine and autonomic nervous systems. Over the past several decades, much has been learned about these systems and their roles in mediating human responses to changing circumstances. A landmark in this line of inquiry was the characterization of several hypothalamic hormones. This research also contributed to an advanced technology for peptide analysis. Coinciding with the discovery of receptors in the brain, it led to a burst of neuropeptide discoveries in the past few years. This rapidly moving frontier is of great significance in understanding brain function and behavior-for instance, responses to stress. It illustrates how advances in neurobiology stimulate the scientific study of behaviour.

Another opportunity arises from research on learning, a major thrust of psychology since its inception as a science. In recent years, a theory has emerged that clarifies the social context of human learning, is a balanced synthesis of cognitive

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psychology and behavior modification, and draws on experimentally verified principles of learning. Such principles are now being used in clinical and field experiments that test ways of changing behavior that affects health. During the past 30 years, epidemiologic studies have delineated objective measures as indicators of the likelihood of developing coronary disease and stroke — that is, risk factors such as high blood pressure, tobacco smoking, and obesity. Several large-scale studies have found that many people can diminish their health-damaging behavior and thereby decrease the likelihood that they will develop serious cardiovascular disease.

The IOM report assembles informed assessments by many leaders in the biomedical and behavioral sciences and highlights promising lines of scientific inquiry pertinent to understanding, treating, and preventing behavior-related components of the burden of illness. The report deals with diverse problems including smoking, alcohol, stress, ageing, cardiovascular diseases, diabetes, mental disorders, sleep, work, and social disadvantage. Given the deep national concern about health and strong data linking behavioral factors and health problems, the delineation of these scientific opportunities indicates a logical response to this great challenge. Therefore the present low level of funding of such research deserves careful reexamination. Broadening of the life sciences in the context of health and behavior can have a profound impact in the remainder of this century.

(Science, 217, 4558 (July 30, 1982) p. 399)

Ten years after Stockholm

by Gilbert F White, Gustavson

In 1972 the Stockholm Conference on the Human Environment marked a peak of public concern for the maintenance of environmental quality. One of its outcomes, the United Nations Environment Programme (UNEP), is celebrating the 10th anniversary of the conference with a "session of special character" on 10 to 18 May in Nairobi, where national and nongovernmental representatives will review events of the decade and lessons to be drawn from them. What can be said of significance for the scientific community?

It is relatively easy to rack up the scores on the legal and administrative measures taken in response to the Stockholm Conference recommendations. UNEP provides a succint account of treaties ratified or not ratified, agencies established, programs initiated, and meetings convened in large number.

It is extremely hard to appraise what, in fact, has happened to the principal components of the environment--the atmosphere, marine environment, inland waters, lithosphere, terrestrial biota, and people. The evidence as reported by UNEP is ragged. The trends that can be discerned with confidence show good news and bad news, and I note a few of each.

Compared with the situation in 1972, the rate of annual population growth in 1980 was diminishing on all continents except Africa. The quality of air in many high-income cities was improving. Likewise, contaminant loads in the inland waters of industrialized countries were generally decreasing. Significant advances were made in reclamation of surface-mined lands and in establishing reserves for the preservation of terrestrial biota.

On the negative side, urban air quality in low-income countries continued to decline. The pollution of certain sectors of coastal waters increased, although the marine production in large sectors grew slightly or leveled off. Deterioration of many semiarid lands and of some irrigated soils expanded. Moist tropical forests were being reduced, but there was a wide divergence among the estimates concerning rates and extent. The implications of increasingly massive alterations in the global cycling of carbon, sulfur, and nitrogen were only beginning to receive integrated analysis.

The assembled data on these and numerous other trends not mentioned here should be critically appraised. While they will no doubt be interpreted in different ways, at least three observations deserve the immediate attention of the scientific community.

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First, as revealed by the difficulty in measuring changes, a more coherent effort needs to be made to monitor key parameters. The expectations of many at Stockholm that an efficient global earthwatch program would soon be put into place proved sanguine. The present deliberate effort should be streamlined and its pace should be accelerated.

Second, it is becoming evident that appraisals of all but a few basic changes such as those in atmospheric carbon dioxide or ozone are most meaningful on a regional basis, where the intertwining of biological, physical, and social factors can be examined in context. Promising advances, for example, have been made in looking at regional seas rather than at the oceans as a whole.

Third, the scientific grounds for measures to correct much of the degradation in soil, water, biota, and air are well known, but there needs to be more systematicanalysis of ways of overcoming social and political obstacles to undertaking them. While speculation runs high on questions of long-term climate change, the quiet degradation of biotic and soil resources proceeds.

The decade after Stockholm has shown that environmental improvement can be achieved, that the pace is slow in many areas, and that scientific inquiry can help speed it up.

(Science, 216, 4546 (May 7, 1982) p. 569)

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Toxin treatment

A tiny drop of the highly toxic nerve poison from the bacillus Clostridium botulinum can cut out the need for the surgeon's scalpel as a treatment for crossed eyes.

Dr. Alan Scott, of the Smith-Kettlewell Institute of Physical Sciences, San Francisco, is pioneering the technique. He injects a billionth of a gram of a botulinum derivative into the muscles that control the abnormal position of the eyeball. The toxin switches off the nerve signals to the muscle for a week or two. The muscles relax, and the muscle on the opposite side takes up the slack and becomes tighter.

If doctors repeat the process often enough, the eye muscles regain their normal balance, and restore binocular vision. About 60 000 Americans undergo operations to correct crossed eyes every year — the toxin could work for half of them, Dr. Scott said.

(New Scientist, 94, 1308 (June 3, 1982) p 635)

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The funding of university research
A comparative study of the United Kingdom and Canada

by I.D. Chapman et al.

(Abstract)

"...This paper extends previous work concerning the allocation of resources through the mechanism of peer-adjudicated grants in the Science Research Council to the National Science and Engineering Research Council of Canada. The aim of this research has been to draw comparisons between the flows of these research resources from the research councils to the universities in the United Kingdom and Canada over the period 1964 to 1974 inclusive. The paper analyses the data using two indicators; one which measures concentration of resources and another which measures the median level of support for a given field. The principal results suggest for both countries that the concentration of resources is not a function of their availability; that the concentration of resources has tended not to vary over time; and that concentration has increased with the level of institutional aggregation. The main differences between countries are that the Science Research Council tended to have the higher level of concentration at the level of the scientist but that the National Science and Engineering Research Council had higher levels of concentration at the department and university levels.

With regard to median levles of support it appears that for both countries the levels of support have remained constant or declined over time; and that there are national differences in the costs of research in areas supported by the two research councils. The implications of these findings are discussed with reference to the dynamics of the peer-review system".

(Research Policy, 11, 1 (February, 1982) pp 15-31)

Extraterrestrial body hits Earth — millions die

The death of the dinosaurs, or rather the nature of the Cretaceous-Tertiary boundary event, continues to exercise the scientific imagination. The latest contribution turns things slightly on their heads and lengthens the chain of causality somewhat. An international 20-strong team has suggested that an extraterrestrial body hit the Earth, that this killed the microscopic plants in the surface waters of the ocean, and that this mass death set off a domino effect that included the end of the reign of the dinosaurs (Science, vol 216, p 249).

The extraterrestrial object already has a great deal of evidence in its favour. Probably the strongest is the so-called iridium anomaly. There is an abnormally high concentration of the metal iridium in the clay thatmmarks the boundary between the Cretaceous and Tertiary eras. Wherever suitable marine sediments of the right age are examined, the high level of iridium shows up. Iridium is rare on the surface of the Earth because, quite dense, it sank to the centre of the planet while the Earth was still molten. But it is more common in space, so the anomaly could be the remnant of something — an asteroid or a comet — from space. The question is how the space object caused the mass extinctions.

Kenneth Hsu, of the Swiss Federal Institute of Technology, and his team devised their new story after a thorough study of a core of sediment removed from the bottom of the ocean off the west coast of southern Africa.

The iridium anomaly was there, as expected, right at the clay that marks the boundary. There were also anomalies in the amount of calcium carbonate—chalk— in the core. Below the CT boundary there is the usual 40 per cent chalk, and well above it the level is again 40 per cent. But between these points there are two distinct minima, one in the clay boundary itself and one about 2.5 metres above the boundary.

Calcium carbonate is important because it can reveal what was happening in the oceans and the air above. Marine organisms use bicarbonate ions in the water to build their chalky shells which are the source of the chalk that rains down to form the sediments. The carbon and the oxygen in the chalk provide information about the temperature of the water in which the organisms lived.

To analyse the oxygen and carbon isotopes, Ramil Wright picked out specimens of Gavelinella beccariiformis, a deep-sea

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species that occurs on both sides of the CT boundary. The team also analysed a bulk collection of skeletons from many species, sorting the bigger ones from the smaller; small organisms are more common at the surface.

For the isotope carbon 13 in the bulk samples there were again two anomalies, one at the CT boundary and one about one metre above. Both anomalies represent depletions of the ^{13}C relative to the more plentiful ^{12}C. But the selected samples of G. beccariiformis show no fluctuations in the ratio of the two isotopes. So the anomaly was confined to surface waters and was spread over a period of about 50 000 years.

Oxygen 18 shows fluctuations similar to carbon 13, but they are less clear-cut. There is a peak in oxygen 18 at the boundary, which possibly indicates a drop in temperature at that time, but in general there is a decrease that parallels the ^{13}C decrease and probably reflects a general warming of the water. G. beccariiformis shows the same ^{18}O pattern as the bulk samples; this suggests that the warming affected deep and surface waters, while only the surface waters showed a change in bicarbonate content.

Hsü and his team say that any model must account both for the change at the CT boundary, a temporary change in the carbon content of surface waters, and for the more gradual change that followed during the next 50 000 years. Their own preference is for a drastic reduction in the productivity of the surface waters; the plants there simply stopped growing. This would make the waters more acidic and upset the carbon dioxide balance. The first ^{13}C spike represents this mass death, caused by impact with an extraterrestrial object that sent up a dust cloud, blotting out the Sun and preventing plant growth.

Because the plants were not growing, they were not removing carbon dioxide from the atmosphere. This longer-term build-up resulted in warming by the greenhouse effect, and it was this warming that caused the changes in ^{18}O. The rise in temperature was probably something between 2 and 10°C, and it took 50 000 years for the surviving plankton to recover and adapt to the new regime. (The ^{18}O peak at the CT clay itself could be a cooling of about 8 °C, also consistent with dust in the atmosphere.)

The increase in atmospheric temperature, brought about by greenhouse warming and triggered by the plankton deaths caused by the impact, then killed off the dinosaurs. Or, as an unfortunate misprint would have it, "the dinosaurs became distinct because of thermal stress after a terminal Cretaceous catastrophe".

(New Scientist, 94, 1302 (April 22, 1982) p 210)

Neutrinos: No oscillations?

by M. Mitchell Waldrop

Opening another chapter in a continuing controversy, a team of American, German, and Swiss physicists have reported new evidence casting doubt on the idea that neutrinos exhibit a bizarre phenomenon called "oscillation". The results of the new experiment were discussed by California Institute of Technology physicist Felix Boehm at the annual meeting of the American Physical Society in Washington, D.C.

They thus bring the controversy full circle. Neutrinos, ghostly particles released in certain nuclear reactions, have no electric charge and very little propensity to interact with matter. They do, however, come in three varieties, known as the electron, mu, and tau neutrinos. Since 1931, when Enrico Fermi first postulated the particles' existence, physicists have also assumed that neutrinos are massless, like the photon.

In 1980, however, experiments in the Soviet Union indicated that neutrinos might indeed have a small mass. At the same time, physicists from the University of California at Irvine reported evidence for oscillations: one type of neutrino can turn into another as it moves along, rather as if a swallow were to metamorphose into a hawk. The two experiments were considered mutually supportive, since for mathematical reasons it is impossible for neutrinos to oscillate unless they also have mass.

The massive neutrino concept was immediately taken up in other disciplines. Cosmologists hoped that swarms of massive neutrinos might account for the invisible "missing mass" which seems to exert gravitational effects on individual spiral galaxies and on clusters of galaxies(Science, 30 January 1981, p. 470). Astrophysicists believed that the oscillation phenomenon might solve the solar neutrino problem: that nuclear reactions in the core of the sun should produce far more neutrinos than are observed. The detectors used to date look only for electron-type neutrinos, however, so if electron neutrinos emitted in the sun have changed to something else by the time they reach Earth, then the paucity is explained.

But now researchers from the California Institute of Technology, the Technical University of Munich, and the Swiss Institute of Nuclear Research have searched for neutrino oscillation with a much more sensitive apparatus than the Irvine group's and have found no evidence for the phenomenon. Their work does not directly contradict the Soviet experiment, however, so neutrino mass is still quite possible.

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For a neutrino source, Boehm and his colleagues used a 2800-megawatt power reactor near Gosgen, Switzerland. (Fissioning uranium atoms emit electron-type neutrinos.) Their detector was set up near the containment building, 38 meters from the reactor core. Since neutrinos so rarely pay attention to ordinary matter--they can easily sail through the core of the earth without slowing--the intense flux of neutrinos from the reactor yielded only about three events per hour in the detector. Still, this setup represented about ten times the sensitivity of the group's previous experiment using a 57-megawatt research reactor at Grenoble, France.

The detector responded only to electron neutrinos. Thus, the difference between the number of events expected from calibration measurements made at the core, and the number actually found at the detector, represented the number of electron neutrinos that had oscillated away and changed to some other type as they traveled the intervening distance.

That number, the group concluded after running the experiment from June 1981 to February 1982, is consistent with zero. In technical terms, the physicists were able to exclude the possibility of neutrino oscillations down to a mixing angle of 0.16 and a mass-squared difference of 0.02 square electron volts. This represents a very large region of parameters where oscillations could possibly be found, said Boehm.

In May, the researchers will begin an effort to set still more stringent limits by moving the detector back to a distance of 48 meters from the reactor core. If the neutrinos are going to oscillate at all, they will then have another 10 meters in which to do it. Moreover, comparison of the two sets of data will eliminate calibration uncertainties.

(Science, 216, 4546 (May 7, 1982) p. 605)

A case of retarded astronomical development

The galaxy Centaurus A, also known as NGC 5128, is a strange-looking object. It seems to be an elliptical galaxy, but it is crossed by a dense lane of gas and dust, which are normally associated with spiral galaxies, and it is an active radio source. Various exotic explanations have been invoked to explain its appearance. But now a team of French astronomers has made new observations which suggest that the galaxy is a spiral after all, though one in which the disc is forming late.

Typical spirals have a two-part structure, a central bulge of stars rather like an elliptical galaxy, and a surrounding disc of young stars, gas and dust, in which the spiral patterns that give the class of galaxies its name form. It now seems that Centaurus A conforms to this pattern, but that the stars in the disc have not yet got around to forming, or shaping up into a spiral pattern.

The new evidence comes from spectroscopic studies made at the 3.6 metre telescope of the European Southern Observatory. Michel Marcelin and Jacques Boulesteix, of the Observatoire de Marseille, and Georges Courtes and Brune Milliard, of the Laboratoire d'Astronomie Spatiale, in the same city, have reported their determination of a rotation curve for the Centaurus A system (Nature, vol 297, p.33). By measuring the rotation, they are able to set limits on the mass of the galaxy and its disc, coming up with figures of just over 10^{11} solar masses for the bulge and 8.2×10^{11} solar masses for the disc. The bulge is more luminous, but the disc is more massive.

The French team concludes that Centaurus A is a normal spiral galxy with a thick, unusually massive disc that is still in the provess of settling down and in which star formation has not yet begun. Presumably, this activity explains the radio noise from the galaxy, and overall the evidence removes the need to invoke collision between two galaxies, or the explosion of an old galaxy, to explain the nature of the source.

(New Scientist, 94, 1307 (May 27, 1982) p. 572)

Spaceseeds

Of all biology's mysteries, the origin of life holds the greatest fascination. A recent proposal, that life on Earth was "seeded" from space, has received support from an American physicist working inthe Netherlands. Dr. J. Mayo Greenberg, of the University of Leyden, spoke at NRC last November on his laboratory investigations of how complex organic molecules might be formed on the surfaces of interstellar dust grains.

According to Greenberg, clouds of gas and dust drifting among the stars can achieve a density capable of obscuring the light behind them. Clouds of such thickness, subject to the stress of radiation from nearby stars (which themselves may be forming within the clouds), are known to exhibit chemical activity. Interstellar dust grains are believed to be composed of silicate or "rocky" cores surrounded by a layer of "dirty" ices containing hydrogen, oxygen, carbon, hitrogen and other elements in various molecular arrangements. Greenberg duplicated the structure and environment of the grains in his laboratory in order to study the changes brought about by ultraviolet radiation similar to what exists in space.

As anticipated, radiation stress caused many of the compounds found on the ice sheath to break up or dissociate. Unexpectedly, however, many of the samples were found to fluoresce brightly and even "explode" expelling many of the compounds as a gas. This suggests an explanation as to why cosmic dust and gas are so often found intermixed in space. Dr. Greenberg's experiments also led him to suggest that the clouds of dust in space interact with nearby stars to create complex molecules currently being catalogued by Canadian radio astronomers (see Science Dimension, 1981, No. 4). Such a cloud drifting near our Sun may have deposited material on the Earth's surface. Finding hospitable conditions, so the conjecture goes, the molecules could have begun the complex associations that ultimately led to life.

(Science Dimension, 14, 2(1982)

Hole in space was a fuss about nothing

Last year's claim that there might be a 'hole in the Universe' -- a huge tract of space empty of galaxies -- understandably created a stir both in the astronomical trade and the popular press (New Scientist, vol 92, p 102). But further studies of the region of the sky around the constellation Boötes now show no shortage of galaxies in the 'hole' reported by a team from the Kitt Peak Observatory in Arizona (Astrophysical Journal, Vol 255, p L1).

The reason for the claim and counter-claim is a fundamental difference between the technique used by the Kitt Peak Team and that now used by Vicki Balzano and Daniel Weedman, of Pennsylvania State University, to probe the depths of the Universe. The original discovery of the supposed hole depended on measurements of all the redshifts of galaxies found in each of three small regions of the sky around Boötes. Since redshift is an indicator of distance, the team in effect looked through tubes along the line of sight to measure the distribution of galaxies with distance from us, rather than their two-dimensional distribution projected on the sky. Each of the three 'boreholes' showed an absence of galaxies at redshifts corresponding to distances between 300 million light years (100 Megaparsecs) and 600 million light years (200 Mpc).

The technique was rather like taking a plum pudding and thrusting three knitting needles through it. If none of the needles strikes a plum, you might think that the pudding was in fact devoid of plums. But you might just have been unlucky with your probes. That is how the Kitt Peak survey now looks in the light of Balzano and Weedman's study.

The new study looks at the whole region of sky around the three boreholes through Boötes. There is a large sample of galaxies - the Markarian galaxies — whose redshifts have been measured, and 113 of them lie in this region of the sky. They do not, by any means, include all the galaxies in this part of the sky, but since they were not selected by redshift, their redshift distribution should give a guide to the overall distribution of galaxies in this part of the Universe. Out of the 113 relevant galaxies, 12 lie within the suspected void, and the overall distribution of redshifts in the Markarian sample is just what would be expected for a uniform distribution of galaxy clusters out to redshift distance of about 1000 million light years (300 Mpc).

(New Scientist, 94, 1304 (May 6, 1982) p 355)

Low-energy electron diffraction for surface structure analysis

by F. Jona, J.A. Strozier et al.

(Abstract)

Low-energy electron diffraction (LEED) is the most important technique for studying the atomic structures of crystalline surfaces. This review aims to give an introduction into the experimental, theoretical and analytical procedures needed for a successful structure determination. After a brief introduction that gives some historical background and sets the problem in perspective, the experiment is described. The fundamentals of two-dimensional crystallography are discussed and their application to LEED are described. The calculation of diffracted intensities requires the development of N-beams dynamical theory, which is discussed next, together with the need for appropriate computer programs. Since the analysis is based on trial-and-error methods some attention is paid to the development of structure models, the problems caused by the co-existence of equivalent domains, and the procedures for evaluating the postulated models. Finally, a brief discussion of the accomplishments is given which, rather than comprehensive, is an assessment of the present state of the art in surface crystallography.

(Report on Progress in Physics, 45, 5 (May 1982) p 527)

Proteins that keep genes under control

Many of the proteins associated with the DNA of higher organisms are arranged as small bundles or "beads" called nucleosomes. Much of a cells DNA is wound around these nucleosomes, which are connected by relatively free stretches of DNA. The discovery of nucleosomes prompted much speculation as to whether or not they occupied precise positions on the DNA, and whether they were involved in controlling the activity of genes. Stephanie Wittig and Burghardt Wittig of the Free University of Berlin believe they have shown that the activity of a gene can be directly influenced by the position of its nucleosome (Nature, vol 297, p 31).

They have devised a complex in vitro system which can direct nucleosomes to form at chosen sites on a gene. This in itself is a significant achievement because most nucleosome assembly systems allow little control over where nucleosomes form along a stretch of DNA.

They chose to study the gene that makes one of the transfer RNA molecules in chick embryos. They directed a nucleosome to form at one of eight different locations along the gene, and then monitored the effect of the nucleosome's position on the gene's activity.

The position of the nucleosome was found to have a profound effect. In two of the arrangements the gene worked very well, while in the other arrangements the activity of the gene was strongly suppressed.

In both of the efficient nucleosome positions a sequence of five nucleotides (the chemical units that link together to make DNA) was aligned with the middle axis of the nucleosome. This sequence was found to be the same as the sequence recently identified as a 'promoter' for the transfer RNA gene(a promoter is a stretch of DNA that is essential for a gene to be efficiently copied into RNA).

The promoter sequence actually occurs very often in the DNA of the chick embryo, and the German scientists suggest that for it to act as a promoter it must be associated with a correctly positioned nucleosome. Significantly, the arrangement of the promoter and nucleosome that allowed the gene to work most efficiently in the in vitro system is the same as is found in active genes extracted from whole cells.

If the control of gene activity by nucleosome position seen in these in vitro studies mirrors what happens in vivo then nucleosomes could be destined to play a large part in future theories of gene control.

(New Scientist, 94, 1307 (May 27, 1982) p 572)

What limits photosynthesis?

by Christine Foyer, Richard Leegood et al.

Enhanced plant productivity is one means by which world food and energy shortages may be alleviated. For this reason research into the photosynthetic process is increasingly favoured both in the UK and overseas. However, the crop physiologist is quick to remind us that the connection between photosynthesis and productivity is more apparent than real, in the sense that a correlation between short-term measurement of photosynthetic rate and crop yield is not easily demonstrated. Certainly the gulf between the plant scientist and the farmer is considerable. Even the highly valuable contributions of the plant breeder have been largely confined to factors such as disease resistance and the redistribution of assimilates within the plant. We have all lamented photorespiratory loss, worried over the inadequacies of ribulose bisphosphate carboxylase/oxygenase and wondered if we can turn, for solace, to C4. Perhaps, however, if we pause for thought, there is no reason to be unduly pessimistic about the future of photosynthesis in its relation to agriculture.

Plant growth is the best measure of net photosynthesis that we have and the limits to which the useful redistribution of assimilates can be achieved are fast being reached. To increase plant productivity by securing more vigorous growth through more effective photosynthesis we need to determine which existing limitation might be removed. A discussion meeting was organized by the Agricultural Research Council to identify and characterize the reactions which limit the photosynthetic process in various environmental and developmental conditions, and to determine how basic research into photosynthesis may be directed towards increasing plant productivity. A workshop on the methodology and applications of the measurement of chlorophyll fluorescence preceded the meeting. This technique is now regarded as a valuable non-intrusive probe for photosynthesis <u>in vivo</u> providing, in the words of J. Barber(Imperial College, London), a 'stethoscope' for plants.

Many workers in photosynthesis disagree about the basis on which the rate of photosynthesis should be expressed, and doubt the validity of the present methods, especially since a single factor is unlikely to be constant. All quantitative means for expressing photosynthetic rate in current use(for example, ground area, fresh weight) carry inescapable disadvantages. In spite of this, chlorophyll is likely to remain the universal basis for expressing photosynthetic rate at the

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cellular level simply because it is easily measured(J. Ludwig, GCRI, Littlehampton). The use of the term 'photosynthetic efficacy', to relate capacity to performance(that is, an assessment of the actual performance of a given crop as a function of the potential performance), could help to determine the degree to which photosynthetic capacity is realized in a given circumstance (D.A. Walker, Sheffield University).

Although the basic climatic limitation to crop photosynthesis is the seasonal input of light energy, the degree to which this energy can be used by the plant is modified by local climatic factors, such as temperature, water and the requirements of particular farming systems (J.P. Cooper, WPBI, Aberystwyth). The rate of photosynthesis reaches a maximum at or just before full leaf expansion and declines thereafter. The length of the growing season before leaf senescence is, therefore, a limitation on crop yield(H. Thomas, WPBI, Aberystwyth). The efficiency of photosynthesis in relation to the balanced excitation of the photosystems is believed to be controlled by the phosphorylation of the light-harvesting chlorophyll a/b binding protein. Balanced excitation is necessary for efficient non-cyclic electron transport and also serves to poise cyclic electron flow by increasing excitation of photosystem I relative to photosystem II. Furthermore, the flexible distribution of available quanta between the two photosystems can be especially important under stress and allow a more efficient distribution of excitation in different cells of a leaf and different leaves in a canopy (P. Horton, Sheffield University).

The majority of temperature crops, particularly cereals, are exposed to suboptimal temperatures for most of their lives. Dramatic differences in temperature response occur between cold-tolerant and cold-intolerant plants. Even at the level of the chloroplast the partitioning of assimilate may be considerably influenced by temperature as transport generally outstrips production at low temperatures; the autocatalytic Benson-Calvin Cycle does not obey Arrhenius' law (Heber, Wurzburg University). Low temperatures cause phase changes in the lipids of the thylakoid membranes and the resulting reduction of the fluidity of the thylakoids reduces the mobility of the electron carriers between photosystems I and II, for example by diminishing the diffusion rate of reduced plastoquinone (D. Chapman, Imperial College, London). This may well be the most temperature-dependent step of electron transport.

Ribulose bisphosphate carboxylase/oxygenase is the point of entry of carbon into the Benson-Calvin cycle and that of

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oxygen into the photorespiratory pathway. There is a broad correlation between ribulose bisphosphate carboxylase activity extractable from leaves and light-saturated rates of photosynthesis in plants taken from a wide range of growth conditions and genotypes. Ribulose bisphosphate carboxylase appears to limit photosynthesis only in the sense that the activity of the enzyme is close to that of the flux through the Benson-Calvin cycle. Plants synthesize only as much of this enzyme as they need (A. Keys, Rothamsted Experimental Station). This raises the question of whether a limitation imposed by this enzyme is a phenomenon perceived by the manipulator rather than the plant.

The purpose of photorespiration continues to be hotly debated. Selective inhibition of the oxygenase activity is improbable although some species have carboxylases with a significantly higher affinity for CO_2 than others (S. Gutteridge, Rothamsted Experimental Station). Other enzymes of the Benson-Calvin cycle, such as fructose bisphosphatase, show changes in activity in response to the redox state of ferredoxin, although the changes in fructose bisphosphatase activity do not have a role in regulation of the photosynthetic rate in leaves illuminated with saturating light.

No final answer as to 'What limits photosynthesis' arose from the meeting. The most popular candidate, proposed by O. Bjorkman (Carnegie Institute of Washington), was God. The question deserves future consideration and research if we are to secure increased plant productivity.

(Nature, 298, 5872 (July 22-28) p. 326)

Is oxytocin an ovarian hormone?

by D. Claire Wathes & R. W. Swann

(Abstract)

Oxytocin is a nonapeptide hormone produced by the hypothalamus and released from the posterior pituitary. It is cleaved from a large molecular weight precursor which is synthesized in cell bodies of hypothalamic magnocellular neurones and then packaged into membrane-bound granules. During axonal transport the precursor is cleaved to produce oxytocin and an oxytocin-related neurophysin. Apart from its established roles in lactation and labour, oxytocin is thought to be an important regulator of the oestrous cycle; it causes luteolysis in cattle and immunization against oxytocin increases the length of the ovine oestrous cycle. McCracken has proposed that oxytocin acts by stimulating prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) release from the uterine endometrium and that steroid hormones regulate $PGF_{2\alpha}$ secretion by altering the availability of endometrial oxytocin receptors. Steroids may also have a direct influence on oxytocin release from the posterior pituitary, oestradiol-17β increasing and progesterone inhibiting oxytocin secretion in response to vaginal distension in the goat. However, recent radioimmunoassay (RIA) measurements of peripheral oxytocin levels during the ovine oestrous cycle consistently show that oxytocin and progesterone concentrations increase and decrease in synchrony during the luteal phase, reaching basal levels after luteolysis at a time when oestradiol-17β titres are known to rise. Therefore, there may exist different controls of reflex release and basal secretion of oxytocin, and our discovery of large amounts of oxytocin within the ovine corpus luteum reported here may provide an explanation.

(Nature, 297, 5863 (May 20-26, 1982) pp 225-227)

Insulin Stimulation of nucleoside triphosphatase Activity in isolated nuclear envelopes

by Francesco Purrello et al.

(Abstract)

The activity of nucleoside triphosphatase, an enzyme that regulates nuclear messenger RNA transport, was measured in highly purified nuclear envelopes isolated from rat liver. Addition of picomolar concentrations of insulin to freshly prepared nuclear envelopes directly increased the enzyme activity. The major effect of insulin on this enzyme was to increase the maximum velocity of its activity; no significant effects were seen on the affinity constant. These studies raise the possibility, therefore, that the nuclear envelope is a site where insulin regulates nuclear functions.

(Science, 216, 4549 (May 28, 1982) pp. 1005-1006)

British Biotechnology

Out of the blue

by Judy Redfearn

In an unusual move, the British University Grants Committee is earmarking part of its annual budget to develop a specific topic — biotechnology. The committee plans that £800,000 will be spent in each of the next three academic years on fostering biotechnology in a handful of universities. The committee had previously been reluctant to earmark grants, preferring that universities should spend their income as they wished, relying on the research councils to encourage centres in particular topics by means of research grants.

The scale of the recent budget cuts seems to have prompted a change of heart. The committee, worried that universities may pare all their activities rather than cut them selectively, clearly hopes that earmarked grants will make the future pattern of universities research more pointed. The £800,000 set aside for biotechnology will be taken from the money reserved for restructuring the reduced university system which in the next academic year (1982-83) will be £50 million. Most of that sum is expected to be spent on payments to redundant academics, leaving uncertain the amount available for fostering priorities.

So far, three centres — at University College London, the University of Birmingham and the University of Manchester Institute of Science and Technology — have been awarded annual grants of £100,000 each to develop biotechnology. Five other centres are expected to receive similar grants soon. The money will be paid as a separate item in each of the next three years, after which it will be incorporated in the recipients' recurrent grants.

The grants committee says that the recipients must decide for themselves how to spend their extra money. Nevertheless, it expects them to forge closer links with industry, chiefly by encouraging the process engineering side of biotechnology, to develop postgraduate rather than undergraduate courses and to appoint some permanent staff, thus fulfilling the recommendations of a Royal Society report which nearly two years ago called for twenty more university posts in biotechnology.

The research councils welcome the new grants, seeing no conflict between the grants committee's assessment of priority and their own. The Science and Engineering Research Council, in particular, welcomes the grants as a way of supporting staff and equipment which could not be paid for out of its research awards.

(Nature , 297, 5863(May 20-26, 1982) p. 173)

France ponders biotechnology

by Robert Walgate

France has done no microbiology for 20 years, has few people who understand fermentation or fungi and has never developed food processing technology. This wild exaggeration is the opinion of a francophile British biotechnologist sketching the problems facing France in his field. Now, however, a fairy godmother has waved her wand: the ministry of research and industry in Paris has published a vast programme for biotechnology, to stretch over three years and cost the government FF 600 million (about £50 million). Will she get Cinderella to the ball?

It depends in part on what the report says in a large section marked "Secret and Confidential", which has not been published but which describes the actions to be taken by the ministry in concert with industry. And it depends on whether France can create enough microbiologists, whose star fell faster and further in France than elsewhere when molecular biology turned to the eukaryotic genome. The University of Strasbourg, for example, was granted a new professorship in microbiology last year, with emphasis on biotechnology; it has been unable to fill it, said a spokesman, with anyone with even a smattering of French.

The ministry's three-year programme promises to tackle the problem in partnership with the universities and the grandes ecoles. And the Centre National de la Recherche Scientifique (CNRS), which supports much of the most advanced biology in France, plans to help double the number of French microbiologists.

Meanwhile, several important centres of biotechnology will now enjoy increased support. At Toulouse, for example, there are three laboratories grouped to form a kind of "transfer centre" between research and industry, directed by Professor Jean-Pierre Zaltar (a specialist in gene expression). At Marseilles, there is a laboratory for bacterial microbiology, which will be expanded next year with the help of Orsay biochemist Jean-Claude Patte. At Cadarache, there is a new laboratory for biomass studies run by CNRS in conjunction with the oil company Elf Aquitaine and the Commissariat a l'Energie Atomique, At Compiegne there is the University of Technology with Dr. Daniel Thomas specializing in enzyme technology; in Paris, the Institut Pasteur is working hard to make up for past years; and at the University of Strasbourg, there are well-advanced plans for a laboratory of plant genetics (which is, incidentally, strongly supported by the new report).

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This week's report surprisingly emphasises the plant sciences, with no fewer than ten recommendations for INRA, the agricultural research body. Even Professor Roger Monnier, director of life sciences at CNRS, believes plant science must receive the most attention.

Over biotechnology as a whole, the report considers France to be weakest in production, in techniques of culture of microorganisms and cells, in enzymology, in reactor design, in extraction and purification and in the provision of analytical control equipment. France also suffers because of an "excessive compartmentalization and specialization of disciplines, research organizations and industries" says the report. But it ends on a strong note: now more than ever, France must support fundamental research, which is "the unique source of the unpredictable".

(Nature, 298, 5872(July 22-28) pp. 315-316)

Transplants as guides to brain development

Brain transplant experiments are helping investigators assess the relative importance of the various factors that control b r a i n development

by Jean L. Marx.

(Abstract)

"... Brain transplants, which might seem to be the stuff of science fiction, or perhaps of Gothic novels, are proving instead to be very practical tools for tackling the unsolved problems of mammalian behaviour and brain development. Recent experiments show that pieces of fetal brain tissue not only survive when transplanted into the brain or other sites of recipient animals but thrive there. The transplants often form correct connections with their normal target neurons, in some cases reversing neurological deficits caused by surgical or genetic lesions.

The success of the animal work has already prompted an attempt to treat human patients with Parkinson's disease, a severe neurological disorder, by injecting into their brains tissue that has the potential of remedying the underlying chemical deficiency.

Theuse of tissue transplants to study fundamental questions about the nature of brain development are discussed in the first of two Research News articles in this issue. The second deals with the potential clinical applications of brain tissue transplantation.

(Science, 217, 4557 (July 23, 1982) pp. 340-342)

Now life can begin without the test tube

A new technique that sidesteps many of the ethical problems surrounding *in vitro* fertilisation ("test tube babies") has been developed in Britain and could offer a simpler treatment for childless couples. Although at an early state of development, the technique has already given rise to two pregnancies that seem to be progressing satisfactorily (Lancet, vol 1, p 1031).

The conventional technique pioneered by Patrick Steptoe and Robert Edwards, involves removing the unfertilised egg (oocyte) from the mother, fertilising it with sperm in a petri dish, and reimplanting the resulting embryo several days later in the mother's uterus. The new technique, developed by a team of doctors from three hospitals led by Ian Craft of the Royal Free Hospital in London, leaves the egg and sperm together for less than one hour before returning the egg to the uterus along with 10 000-20 000 sperm. It does not require the egg and sperm. It does not require the egg and sperm to have fused to form an embryo before they are returned to the mother. The operation is much simpler to perform than the "test tube baby" technique. It should not be beyond the expertise of most district hospitals, making treatment more widely available.

Thirty-one infertile women took part in a trial of the technique. All received a fertility drug, clomiphene citrate, for four days during the first week of their cycle to stimulate ovulation, then human chorionic gonadotropin (hCG) on the day the developing ovarian follicle, which contains the ripening egg, reached 20 mm in diameter. The hCG made sure the uterus was ready for implantation. Thirty-six hours later the eggs were collected and incubated for six hours at about body temperature. After adding fresh sperm, the team incubated the egg and sperm together for another hour before transferring them back to the mother's uterus.

Normally, the embryo signals its arrival in the uterus and implantation in the wall by producing much more hCG, whose rising level shows up in the mother's urine. By monitoring hCG in women participating in the trial. It was possible to gauge whether or not implantation had taken place. From their results, the team believes 14 patients started a pregnancy, which ended with their next monthly period, while two patients remain clearly pregnant.

This success rate of 7 per cent (measured by comparing the number of egg transfers to the number of pregnancies) falls considerably below the 25 per cent of successes achieved by the

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more traditional techniques. These depend, however, on fertilising several embryos in the petri dish, to be sure of one success, and controversy surrounds what happens to the 'leftovers'. The new technique sidesteps this problem completely by manipulating oocytes rather than embryos. The authors believe they can improve their rate of successful pregnancies by improving the receptivity of the uterus to the egg through more careful hormonal control.

(New Scientist, 94, 1305 (May 13, 1982) p 417)

End of the world forecast

The end of the world as we know it may be just around the corner in geological terms, 100 million years from now. Jim Lovelock, a Launceston based freelance scientist, and M. Whitfield, of the Marine Biological Association laboratory in Plymouth, make this prediction in Nature (vol 296, p 561) on the assumption that natural processes on Earth cannot obviously provide compensation for a continued rise in the Sun's temperature.

The argument extends Lovelock's earlier work on the 'Gaia hypothesis', which sees life on Earth as part of a complex organism maintaining suitable environmental conditions for life. Many people have noted that when the Earth was young, 4000 million years ago, the Sun was cooler than today, according to standard astrophysical theories. But we know from evidence of running water that the Earth has been about as warm as it is now for all that time. The standard explanation is that the carbon dioxide concentration in the atmosphere has declined from about 7000 parts per million to its present 300 ppm, reducing its warming greenhouse effect and thus balancing the increasing warmth of the Sun.

Lovelock favours the idea that life itself is involved in biological feedbacks which maintain the surface temperature status quo. Others argue that geological processes can expdain the changes equally well. But either way, as Lovelock and Whitfield now point out, a crisis may be at hand.

As the Sun continues to warm, as the astrophysicists tell us it must, then either the Earth will warm or the carbon dioxide concentration must decrease further. Below a concentration of some 150 ppm, however, there will be insufficient carbon dioxide in the air to maintain photosynthesis. It looks as if the natural balances which have kept our planet equable for 4000 million years have tipped as far as they can, and that imbalance will occur in the near future. The crisis will be reached in about 100 million years — "in human terms ...still infinitely distant", say Lovelock and Whitfield, "but in terms of the life span of the biosphere ... we might forecast an end to the long spell of cool and favourable climate".

(New Scientist, 94, 1302(April 22, 1982) p 211)

Massive Chinese plan to divert water resources

two possible routes

"...In China, as elsewhere, good soil and climate are not always found with abundant water for intensive agricultural development. South China has much water but not enough cultivable land, but in north China the reverse is true. The discrepancy is even more pronounced in northwest China, where much land could be cultivated with more water.

Water available for irrigation in different major river basins of China varies greatly, as the following table shows

River basin	Land available	Average runoff
	(10^6 ha)	(m^3/ha)
Chang Jiang	24.0	41.700
Huang He	13.1	4.290
Huai He	12.6	4.230
Hai-Luan	11.3	2.500

Thus while the Chang Jiang basin, with a quarter of China's cultivated land, has ample water, others, like the Hai-Luan, have average runoff of only about 6 percent that of the Chang Jiang.

Many of China's economic activities are concentrated in these basins, and further agricultural and economic developments will take place there. Since water is essential to both, either more water will be needed or water now available will have to be more efficiently used. Both alternatives will probably have to be used in some combination.

Since the Chang Jiang basin has abundant water, and the Huang-Huai-Hai plains do not, many plans have been suggested over the years to transfer water from one region to the other. Three important alternative water transfer plans were proposed in the mid-1950s along the upper reaches (Western Route), middle reaches (Middle Route) and lower reaches (Eastern Route) of the Chang Jiang.

Preliminary investigations were carried out from 1959 to 1961. It soon appeared that the Western Route was not the best solution as it was too long and the terrain was unsuitable.

The water transfer scheme started to receive more attention in the 1970s because of drought in the Huang-Huai-Hai plains and the need for more water for the cities of Beijing and Tianjin. Currently two routes are being considered — Middle and Eastern —

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to carry water to the western and eastern parts of the plain especially.

The Middle Route diverts water from the Danjiangkou Reservoir in the middle reaches of the Han River. The height of the present dam will be raised from 162 m to 175 m, which will increase the reservoir capacity to 33 billion m^3. This done, and the Sanxia Reservoir on the Chang Jiang built, water will be conveyed north through Nanyang basin in Henan province. It will cross Fangcheng Divide, and then Huang He by an aqueduct, then go north along the eastern foothills of Tainhang Mountains to Beijing. The total length of the canal will be 1265 km, and its discharge will be 1200 m^3/s at the headworks, reducing to 800 m^3/s at the crossing of the Huang He and to 120 m^3/s at the edge of Beijing. The water will flow by gravity since the elevation at the headworks is 149 m, becoming only about 50 m at Beijing.

The Middle Route will increase irrigated farmland by 5.14 million ha in Hubei, Henan and Hebei provinces and Beijing. In addition, 7.4 billion more m^3 of water will be available for industrial, mining and domestic uses.

The Eastern Route will deliver water pumped from the Jiangdu station at the lower reaches of the Chang Jiang, which will be carried northward roughly along the Beining-Hangzhou Grand Canal, crossing lakes Hongze, Luoma, Nansi and Dongpi. The total length of the main canal will be 1150 km.

The highest point of the canal will be where it crosses the Huang He through a 0.6-km tunnel, which will be 40 m higher than the Jiangdu pumping station. The current suggestion is to lift water through 15 cascades, with a total lift of 85 m. Large pumping stations will have to be constructed, with a capacity of approximately 1000 MW, and an annual electricity consumption of 3000 to 5000 MVVh.

Thirty billion m^3 of water will be pumped from the Chang Jiang in dry years and 14 bidlion m^3 in an average year. The scheme will provide irrigation for 427 million ha of farmland, of which 2.27×10^6 ha will be to the south of the Huang He and 2×10^6 to its north. An additional 2.7×10^9 m^3 of water will be available for industrial, mining and municipal uses. Unfortunately, topographical conditions make pumping necessary, which uses much energy.

Currently studies are being carried out on both the Eastern and Middle Routes to transfer water from the Chang Jiang to the North China plains. Chinese engineers and scientists are

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now investigating the many technical, economic, environmental and social problems associated with such a major man-made scheme, which would affect a vast geographical area and be the largest water diversion plan ever constructed by man. Fortunately, the Chinese scientists and decision-makers are well aware of both the potential benefits and costs of such a major undertaking. As Vice-Premier Fang Yi has commented, all the alternatives will have to be evaluated before any final decision can be taken.

(Ceres, 14, 6 (Nov. - Dec., 1981) pp. 8-9)

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Birds and aviation

by Victor E.F. Solman

(Summary)

Collisions between birds and aircrafts have caused damage to, or destruction of, aircraft and loss of human life for more than 68 years. Birds are attracted to airfields by the large open spaces which they provide and, often, by the availability of food, water, and shelter, on or near the airfield. Birds attracted by open space can be driven away by trained persons furnished with suitable bird-dispersal equipment, while removal of food, water, and shelter, can reduce the attraction.

Mass movements (migrations) by birds, especially large birds, create hazards for aircraft aloft. Air traffic control radar can show the abundance, speed, and direction of movement, of birds, while correlation of those movements with weather parameters permits development of bird movement hazard forecasts. Although the periods of high hazard are of short duration, use of these forecasts to make changes in flying training programmes has reduced losses of Canadian military aircrafts through bird studies.

Automatic digital presentation of bird movement data gathered by radar has been tested at two airfields by air traffic controllers for possible use in vectoring scheduled civil aircraft away from hazardous concentrations of bird migrants. A decision on operational use of the technique has not yet been made.

Reduction of bird hazards to aircraft depends upon human motivation. The necessary habitat control, bird dispersal and migration hazard forecasting, involve time-consuming, rather dull work that is repeated at prescribed intervals. Unless the work is always well done, bird-strikes on aircraft will continue and human lives and aircraft will be lost.

(Environment Conservation, 8, 1 (Spring 1981) pp. 45-51

Solar flares, proton showers, and the space shuttle

by David M. Rust

(Abstract)

"... The space shuttle era will focus renewed attention on the hazards of the space environment to human habitation. The chief unpredictable hazard for astronauts is energetic proton radiation from solar flares. In some orbits, there is no reasonable level of shielding material that will protect shuttle occupants from potentially lethal doses of radiation. The effects of a solar flare that occurred during the first flight of the Columbia are discussed and current flare research reviewed. The emphasis is on progress made during the recent international Solar Maximum Year toward understanding the origins of proton showers.

(Science, 216, 4549 (May 28, 1982) pp. 939-946)

Big wave channel for fullscale coastal research

Hanover is the site of an item of experimental equipment which does not exist anywhere else in the world, namely a wave channel which for the first time enables the movements of waves and surf to be produced in their natural dimensions so that sand movements, coastal erosion and destruction, and the robustness of dykes, can be studied in natural conditions.

This "big wave channel", as it is called backed by the German Research Association to the tune of roughly Rs.8 crores, will be used mainly to produce a natural imitation of what takes place when surf is formed.

When it is formed at the coast, the energy generated by the movements of the sea is converted to eddies and then to heat.

An astonishing surge of energy is frequently produced in a short stretch of no more than a few metres. Three metre high waves, for instance, generate about 60,000 kilowatts to a single kilometre of beach.

The order of magnitude of this energy conversion when the sea is stormy is testified by innumerable eye-witness reports — for example those on the gargantuan wave which smashed the light in the Tillamook Lighthouse off the Oregon coast in 1891, Despite the fact that it burned 43 metres above sea level. But even at the steep coasts of the Baltic or the North Sea the effects of surf are very considerable and can jeopardise the safety of the dykes.

The energy conversion processes which take place when a wave breaks are extremely complex. A small part of the wave is thrown back seaward, another part is converted to bed currents which drift backwards or sideways (taking bed sediment with them), and another part again generates bed vibration in the surf zone. But a very large part — possibly the decisive part — is consumed, astonishingly enough, as Professor Alfred Fuhrboter of Brunswick Technical College discovered at the beginning of the Seventies, in absorbing air into the breaking water.

When waves break, especially in the case of "white horses", where the crest collapses down an almost vertical wall, a large volume of air enteres the seawater. To date, no exact measurements have been taken of the volume of air in the white surf, but it is assumed to be 50 or 60 per cent in the case of genuine breakers. Such "shock injection" of air calls for a great deal of energy, since every single air bubble has to overcome the skin tension of the water and some of the bubbles are thrust down very deep.

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Furthermore, this mixture of water and air at the front part of a breaker is produced within a very short space of time in a stretch which is equal, perhaps, to half the length of the wave, a fact which concentrates this enormous conversion of energy upon a very narrow strip of beach, where it can cause vast destruction. As the wave recedes, the energy stored in the air bubbles is recuperated and a confused tangle of eddies occurs in which, due to the ascending air bubbles, the water seems to boil.

These processes, perhaps decisive for the conversion of energy in a breaking wave, however, cannot be reproduced with small-scale models and then extrapolated to full scale. It is impossible to create surf and breakers with a few decimetres, of perhaps even only centimetres, of water, since the skin tension is so great by comparison with such a small quantity of wave energy that there are neither "towering" breakers nor any injection of air worth mentioning. The only feasible way is full-scale research.

The "big wave channel", under construction in Hanover near the Mittelland Canal, is due to be opened in 1982.

The installation, planned by Professor Fuhboter and Mr. Joachim Crune, an engineer, both of Hanover University, consists in a concrete channel 324 metre long, five metres wide, and seven metres deep, with a 900 kilowatt "wave machine" at one end which, working in water of five metres maximum depth, generates waves of maximum height of two-and-a-half metres — the type of wave to be expected at the German coast in the roughest seas.

The first item on the programme will be to study modern dykes of the sand core and asphalt cover type, the question being whether they are capable of standing up to heavy "shock waves" where there are cracks, however small such cracks may be. Such "shock waves" occur wherever a mass of water shoots out of a breaking wave, which occurrence, according to Professor Fuhrboter, takes place roughly at every second wave. Some of the stresses and strains which then occur are extreme. About every thousandth "shock wave", for instance, deriving from a three-metre wave, reaches the pressure exerted by a 110 metre head of water. — German Research Service.

(Source: German Research Service)

Nuclear energy prospects to the year 2000 calls for accelerated construction of nuclear reactors

(Extracts)

"... Nuclear Energy Prospects to 2000, was prepared jointly by the OECD Nuclear Energy Agency (NEA), and the International Energy Agency (IEA). Future trends and the potential growth of electricity use in the OECD countries are described in the report as well as future energy demand and supply.

The report presents the most recent assessment of nuclear power growth to the year 2000 and weighs the impact of the nuclear contribution on the overall energy picture. Other major factors influencing the growth of nuclear power, including public acceptance, are also reviewed.

Electrically demand has slowed considerably in OECD countries since 1973, mainly as a result of the world economic recession and higher energy prices. But in the 1980's, according to the report, electricity demand will grow between 2% and 3% annually and between 3% and 4% annually in the period 1990 - 2000, as more electricity is substituted for oil in the commercial, residential and industrial sectors of OECD economies.

Nuclear and coal contributions will need to be expanded to meet future electricity demand, and the accelerated replacement of oil-fired generating plants, the report says. As the report already assumes a very ambitious coal-fired generating programme, any nuclear shortfall will have to be met either by greater use of oil, or by lower energy supply and reduced economic growth. Both of these alternatives would harm the economies of OECD countries.

The report notes that nuclear construction and supply capacity is more than adequate at present to meet projected demands and there are no technical reasons why nuclear power could not expand much more rapidly.

Nuclear power is the most economical way of generating baseload electricity in most OECD countries, but if it is to play its expected role, governments need to decide on early actions in a number of major policy areas, according to the report.

These areas include demonstration of the availability of radioactive waste management techniques, improvement in the efficiency of regulatory and licensing processes and electricity pricing which adequately cover costs of construction of nuclear facilities".

(O.E.C.D., Press Release (July 20, 1982) pp. 1-2)

Offshore mining goes deeper

While the future marine technology for mining ore from the bed of the ocean is still being discussed, offshore tin mining in South East Asia is already well under way. Within the space of roughly a decade, the quantity of tin brought up off the coasts of Thailand and Indonesia has reached a figure which is probably equivalent to at least a fifth of the annual world production.

Offshore deposits in that part of the world are very large, but their workability has been limited by the mining technique employed to a depth of water of 50 metres. A new dredging technique will now make it possible to go down to at least 100 metres.

The Federal Republic of Germany, the Netherlands, and the United States have developed a new type of shovel wheel technique almost simultaneously to overcome the present depth limit; it follows the principle of the shovel wheel excavator used in mining. With such an excavator working offshore, however, the spoils have to be drawn off by suction in order to get them to the surface.

(Source: German Research Service)

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Radioactive waste in India

Looking to glass

by Sunil Saraf

The world's second commercial plant for the immobilization of radioactive wastes from nuclear power generating stations is soon to be built at Tarapur, in the western Indian state of Maharashtra. The first such plant is already in operation at Marcoule in France.

The new plant is being set up in the wake of increasing concern in India that radioactive waste from nuclear power installations might damage the health of the people — although there has been no scientific evidence of such damage so far from India's two nuclear power plants at Tarapur and Kota in Rajasthan state.

The radioactive waste immobilization method being adopted at Tarapur is a semi continuous process which incorporates the oxides of high level waste from fuel reprocessing into borosilicate glassy matrices. The nominal throughput of the plant is about 25 litres of waste an hour, equivalent to the immobilization of wastes produced from reprocessing about one tonne of spent fuel a day. The plant would produce about 125 kilogrammes of glass a day, which is to be stored in stainless steel containers.

The process was developed in India and differs in many respects from the British and French techniques. The wastes are first calcined with glass fines in a process canister and then melted into a glass form. After sufficient "soaking" to help achieve homogeneity, the glass is cast into storage canisters — which can be inexpensive containers as the glass waste is more easily stored than liquids.

The storage unit are stored in an engineered near surface facility where they undergo continuous natural draught cooling to dissipate the decay heat under constant surveillance. The plant is designed to provide cooling for 20 to 30 years and incorporates facilities for establishing the characteristics of the waste products when the time comes for ultimate disposal.

The ultimate disposal medium has not yet been chosen, although current research favours a hard rock formation such as gneisses or granite.

The high level radioactive wastes arise from the reprocessing of spent uranium fuel for the extraction of plutonium. The

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Atomic Energy Commission now proposes to build a chain of reprocessing plants in the country near the sites of future nuclear power stations. The proposal follows the United States' refusal to provide enriched uranium for the Tarapur nuclear power plant unless India meets conditions specified by the United States in the name of nuclear non-proliferation. Plutonium extracted by the reprocessing of spent fuel would therefore substitute for supplies of enriched uranium withheld in this way.

(Nature, 296, 5860 (April 29 - May 5, 1982) p 795)

Let there be light

Lasers could save 13,000 Americans from blindness in the next year, according to the director of the US National Eye Institute. They are victims of a condition called senile macular degeneration — a progressive disease that manifests itself through abnormal bleeding in the eye. It is a major cause of blindness in the over 50s.

Three years ago, the institute set up a five-year study to investigate how lasers could overcome the problem. Last week the study came to an end because the technique is so successful that no further studies were necessary.

The study involved 200 people suffering from senile macular degeneration. Doctors sealed off blood vessels in their eyes with finely-focused laser beams. The man who coordinated the research, Dr. Stuart Fine of the Johns Hopkins University in Baltimore, said the results were unequivocal. The laser treatment halted the onset of blindness in up to 70 per cent of the patients who received the treatment in the early stages of the disease.

Only 25 per cent of treated eyes lost their sight, Fine said, compared with 60 per cent of untreated eyes. "The trial yielded results far sooner than we had expected", the eye institute's director, Dr. Carl Kupper, said, "We believe that these findings may save as many as 13000 older Americans from going blind in the next year".

(New Scientist, 94, 1305 (May 13, 1982) p. 405)

The chemistry of fossil plants

by Karl J. Niklas

(Summary)

"... The study of fossil plant chemistry is a new field, relying heavily on the vast biochemical data available from studies of modern plant taxa and limited by the paucity of detailed analyses of fossil taxa. Despite the difficulties presented by extremely altered chemical profiles and contamination, preliminary studies reveal a wealth of information from which taxonomic and phylogenetic relationships may be deduced. In general, the level of chemotaxonomic resolution achieved decreases as the age of the material increases. Analyses of Silurian material demonstrate the potential to resolve tracheophytes from nontracheophytes. In studies of Paleozoic fossils, suprageneric relationships comparable to those based upon morphology can be resolved by chemical means, while more subtle levels of taxonomic assessment are possible in dealing with relatively recent, Tertiary fossil remains. It is, however, anticipated that as the sophistication of the techniques used increases and as the theoretical backdrop against which the data are analyzed broadens, the utility of paleobiochemical analyses will become increasingly more obvious and useful to the paleobotanist and evolutionist.

(Bioscience 31, 11 (December 1981) pp. 820-825)

Salt of the Earth is more trouble than it's worth

Some archaeologists believe that the great civilisations of the Tigris and the Euphrates collapsed because salt levle in the soils became so high that crops would not grow. The problem is one of lands with dry climates, and it is becoming progressively greater in the southern half of Australia, and in other dry regions such as parts of the US.

Curiously, salting reflects a problem of too much water rather than too little. In wet countries, salts leaching out of the rocks below the soil rapidly wash to the sea. In dry ones this washing out does not occur, and salt accumulates in the subsoil. Flood irrigation raises the level of the water tables and the salt in the subsoil rises to the surface to cause salinisation. Clearing natural vegetation has the same effect. The natural vegetation in dryer Southern Australia uses all available water. Crops do not, and so even without irrigation water tables can rise and bring up the salts from below.

According to Maurice Mulcahy of the Western Australian conservation and environment department, about half of the 18 000 square kilometres of Australia suffering from salinisation is valuable land under irrigation. The rest is land that has been cleared for grazing. However, he pointed out that while salting has reduced agricultural output, rising salt concentrations in rivers like the Murray that provide the water supply for the country's coastal cities present an even more immediate threat.

The problem, Mulcahy suggested, is not one of lack of knowledge about the causes, or one of not knowing in theory what to do. Various agronomic and engineering solutions are available. Obviously, in both irrigated and non-irrigated areas management should aim to use all the available water to gain the maximum crop production. (Doing this would minimise the movement of water in the soil.) Rather, the problems are economic and social. Who should pay the high costs involved — the government, individual farmers, or some greater social groupings?

Carey commented that a common strategy for dealing with the salting problem has been to encourage farmers to form groups by providing them with government grants and low interest loans for capital works. However, judging from the experience of similar schemes to encourage soil conservation, farmer groups often come together purely to obtain the government hand-out rather than genuinely to improve their water management practices.

(New Scientist, 94, 1307 (May 27, 1982) p 573)

Bugs to the oil industry's rescue

by Derek Springham

Political and financial quirks aside, oil is an increasing scarce commodity. Tue or false? Well, both. Present techniques may get no more than 45 per cent of the world's known oil reserves out of their subterranean reservoirs. But on that basis, when the oil has 'run out', more than half of it is still there—4 million million barrels of oil. What can one do about this? The oil industry's answer is something called enhanced oil recovery(EOR), the most fantastic version of which would use microorganisms-live bacteria—to help out.

Oil is trapped underground, not in vast caverns (as many people imagine), but in porous sandstone or carbonate rocks. The oil, which is less dense than water, is prevented from escaping upwards by a dome of impermeable rock. Frequently, the oil-bearing rock is in contact with a layer containing gas at high pressure above it, and a layer containing water below. The first stage of oil extraction (called primary recovery) involves drilling a well down into the oil-bearing layer. Oil is then forced to the surface by expansion of the gas above it; by gas dissolved in the oil coming out of solution; and by the influx of water.

Oil production by these mechanisms will eventually slow down; at this point only a small proportion of the oil will have been produced. To extract more oil, so-called secondary recovery procedures must come into play. These involve drilling additional wells (known as injection wells) into the aqueous layer below the oil-bearing stratum and pumping down water. This serves to maintain reservoir pressure and to push the oil through the porous oil-bearing rock as it moves towards the production well. Ideally, the water should move through the porous rock on a discrete front, pushing the oil ahead of it. In practice, the water finds the paths of least resistance through the intricate network of oil-bearing channels leaving behind much of the crude oil which is more viscous than the water. At the production well, water begins to come to the surface together with the oil and, as time passes, the oil/water ratio decreases until eventually it is uneconomic to continue production. On average, primary and secondary procedures between them will extract about one third of the original oil.

In addition to the conventional techniques described above, reservoir engineers have a battery of 'enhanced oil recovery'(EOR) techniques, which fall into three main categories: thermal, miscible and chemical. With the first engineers literally steam the oil off the walls of the porous rock; with miscible materials, they

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pump in gases or liquids (CO_2 for example) that mix with the oil and thus reduce its viscosity. Chemical methods are more general but their main aim is to help the water pumped into the well under pressure to push more oil out; some chemicals thicken the water so that it drives the oil out more effectively; others reduce the surface tension of the oil.

At present the economic advantages of EOR techniques are often questionable and, because many of the substances used in them are themselves derived from oil they may reduce the amount of oil available for other purposes. So why is the oil industry, normally so conservative, prepared to back something so speculative that even the scientists are hedging their bets? The answer is that the potential technical and commercial rewards are huge.

Clearly it would be of the utmost benefit to have available an EOR technique which uses cheaper materials and in which the active substances do not become absorbed, dispersed or degraded as they pass through the reservoir rock. Surprisingly, a technique which may have the required features was proposed by an American microbiologist, Claude ZoBell, as long ago as 1945. ZoBell pointed out that many bacterial generate metabolic products (for example, gases such as carbon dioxide, various surfactants, and polysaccharides which increase the viscosity of water) that are the sort of substances useful for enhanced oil recovery. He suggested that carefully-chosen cultures of bacteria pumped into oil with the water put in during secondary recovery and provided with cheap sources of organic carbon such as molasses, might grow, synthesise their metabolic products, and release oil. The great attractions of this method, known as microbial enhancement of oil recovery (MEOR) are that cheap raw materials are used. Also because the active materials are produced by bacteria distributed throughout the reservoir, the need for the materials to survive a long passage through the rock before reaching the oil is eliminated as bacteria are alive and self-propagating. The concept promised much more efficient extraction at greatly reduced operating costs.

At the time ZoBell made his proposals, oil was cheap and plentiful and there was little stimulus to invest large sums of money in developing methods which were only speculative. However, results from several experiments over the years—one or two in the US, and several in Eastern Europ—illustrate both the promise and the limitations of such techniques.

Between 1947 and 1955 Vernon Coty, David Updegraff and Hank Yarborough, of the Magnolia oil company (now part of Mobil), conducted a series of laboratory simulations of microbial EOR

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followed by a field trial. They used cylinders of porous sandstone saturated with oil in the laboratory to simulate reservoir rock. They forced water through the rock to simulate waterflooding and they showed that cultures of the anaerobic bacterium Clostridium acetobutylicum, with a substrate of molasses, could increase the amount of oil released. Their field trial was in Union County, Arkansas, on a pair of wells which had been subjected to waterflooding for some years and from which an unusually high proportion of oil had been extracted. They injected a 2 per cent solution of molasses as a bacterial nutrient at rates ranging from 100-500 barrels per day for the first six months of the experiment and pumped in about 1800 litres of bacterial culture.

Before the experiment the output of oil from the corresponding production well 122 m away, had been declining steadily. The expected output for the experimental period was 0.6 barrels per day, and this part of the field was virtually at the end of its useful life. In the third month of the experiment, the output from the production well started to rise and remained well above the expected level until it ended nine months later. During this period the mean output of oil was 2.1 barrels per day. As oil production increased, a variety of typical products of bacterial fermentation appeared at the production well; short-chain fatty acids, carbon dioxide, traces of ethanol, butanol and acetone. The engineers and microbiologists agreed that oil production had increased significantly, and was due to the bacterial treatment although they could not identify the precise mechanism involved.

Now that oil prices are so high in real terms, and a long term shortage of supplied is looming, MEOR techniques are attracting more interest. If efficient and reliable techniques can be developed there are plenty of oil fields to use them on. In the US, for example, are hundreds of thousands of wells which have been abandoned or currently produce little oil. In most cases the bulk of the original oil is still in the ground.

Many engineers fear that the injection of bacteria might damage oil reserves. There are several potential dangers. Sulphate-reducing bacteria, a widely distributed group of anaerobes, can contaminate oil with the highly toxic gas hydrogen sulphide. Such 'souring' can corrode pipes, and can block them by producing insoluble sulphide precipitates. Other bacterial products such as ferrous hydroxide and extracellular slimes can also cause blockages.

Andrew McKay at Queen Mary College in London is studying how Pseudomonas putida, labelled with radioactive phosphorus move through columns packed with microbeads or through cylinders of porous rock. He monitors the emergence of bacterial cells

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using continuous flow scintillation counters and can detect any tendency to block the column by measuring increases in pressure across the column. So far, the bacteria penetrate the columns with permeabilities well below those of oil-bearing rocks in the North Sea.

At the University of California, Los Angeles, Teh Yen is approaching the problem in a different way. He is making artificial bacteria out of microspheres of a polymer of the sort used for making soft contact lenses, and seeing how they move through porous rock. The properties of these spheres can be varied to study, for instance, the effect on the movement of the bacteria of their density and size and of changes in nature of their surfaces.

In the North Sea, where most of Britain's oil is, the conditions are exceptionally difficult for microbial EOR. Extreme weather conditions make operations on oil platforms difficult and expensive, the oil bearing rocks are deep and at high temperatures and pressures, which prevent most bacteria from growing. Because of the high cost of drilling, wells are widely separated so a MEOR process would have to function over large distances and for long periods of time. With several hundred yards between adjacent wells, water would take about seven years to move from injection well to production well. Nonetheless it seems well worth while trying to use microbial technology. We calculate that when conventional techniques have been fully exploited, at least 20 000 million barrels of oil will remain in Britain's sector alone.

Much of our research at Queen Mary College (sponsored by Britain's Department of Energy) is designed to cope with the special conditions in th north Sea. The addition of bacterial nutrients such as molasses is out of the question on such a huge scale, and an MEOR field trial would have to run for many years before an increase in oil production could be expected. Even if oil companies could overcome the logistic problems of transporting molasses to the oil platforms the cost would be prohibitive. We argue therefore, that the only possible organic nutrient for the bacteria is an ingredient of the oil itself. The only extra nutrients required would be mineral salts which are cheap and can be transported easily as dry powders. The snag was that until recently scientists had found no bacteria that could be grown on crude oil without molecular oxygen. It would be impracticable to introduce oxygen into reservoirs in the required amounts and indeed engineers go to some trouble to exclude it to avoid corrosion of pipework. We accordingly decided to search for bacteria that could break down crude oil without oxygen.

We established hundreds of enrichment cultures, many containing nitrate ions to encourage the growth of nitrate-

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reducing bacteria — a group of organisms that can use nitrate as an oxidising agent instead of molecular oxygen. In some of these cultures, growth could be detected by changes in the opacity of the water containing the inorganic nutrients in which the bacteria will live (known as the growth medium) by an increase in bacterial protein, by the production of gas and by the appearance of large numbers of bacterial cells under the microscope. Clive May and Melanine Brown at QMC are studying the metabolism of these cultures and attempting to purify the bacteria and understand how they work. They have maintained cultures for over a year by periodically adding extra 'growth'medium' and crude oil. When fresh growth medium is added, the cultures produce carbon dioxide and form nitrite. After a few days the nitrite disappears and molecular nitrogen is evolved. The whole process depends on the addition of crude oil and does not require molecular oxygen. The growth medium is boiled before use to remove oxygen and allowed to cool in oxygen-free nitrogen. In many cases, the experiments have been carried out in anaerobic tents as an additional precaution against the entry of oxygen (in some experiments small quantities of oxygen were deliberately added to cultures and inhibited their growth). We are convinced that our cultures can metabolise some components of crude oil in the absence of molecular oxygen but not which ones.

Physical conditions in North Sea reservoirs are extreme: for instance, the temperatures range from around 90° C in the Forties field to about 120°C at Magnus. These temperatures would quickly kill most microorganisms and might seem to rule out a process which would depend on bacteria being able to grow for many years. Bacteria known as 'extreme thermophiles' or 'caldoactive bacteria' can grow at high temperatures but until recently 85°C was the hottest at which they had shown prolonged growth under laboratory conditions. Nevertheless, Thomas Brock of the University of Wisconsin-Madison showed in the 1960s that this was not the absolute limit for bacterial growth. He demonstrated the presence of living bacteria in thermal springs up to 100°C by immersing microscope slides in the water for a day or more. On removal, the slides were covered with bacterial growth, although he could not keep the cells growing at the same temperature in the laboratory.

Malcolm Foster has been trying, at QMC, to extend the limits for growth of a hot spring thermophile which would grow readily at up to 80° C. He aims to select mutants with an extended temperature range using a system of continuous culture, known as the 'turbidostat', in which the bacteria

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could be kept growing for several weeks at a temperature high enough to slow their growth rate without preventing growth entirely. We expected that natural mutants that could tolerate high temperatures would outgrow the existing strain and take over the culture. So far, we have achieved only modest increases in the maximum temperature at which we can maintain growth and these increases may be due to other factors. Meanwhile, we have obtained a highly promising culture of an anaerobic bacterium that grows in a hydrogen-carbon dioxide atmosphere at temperatures as high as 92°C, sufficient to permit operations in quite large regions of the North Sea.

High pressure is another adverse condition in deep oil-fields and pressures up to 300 atmospheres are characteristic of the North Sea's reservoirs. Many bacteria are prevented from growing by such pressures although others are unaffected. The critical problem, which we are now investigating, is the way in which temperature and pressure interact in their effects on bacterial growth.

Edward Grula at Oklahoma State University is examining anaerobic bacteria of the genus Clostridium to find strains that release oil efficiently. He uses small pieces of limestone or sandstone rock impregnated with crude oil under vacuum. Excess oil is removed and the rock is covered with a nutrient medium, inoculated with the bacterial strain to be tested, and incubated. When oil is released it floats to the surface.

Another group, led by Bennett Clark at the University of Oklahoma is also searching for organisms that can assist the movement of oil. The scientists are concentrating on organisms that produce polymers to thicken the water pumped into the reservoir. They are also trying something highly unusual—seeking ways of oxygenating reservoirs to permit aerobic bacteria to grow. The dangers of this technique are the highly corrosive nature of oxygen for metal pipework and that oxygen may stimulate undesirable bacteria in the reservoir. William Finnerty of the University of Georgia is taking another interesting angle. He is examining organisms that can attack very viscous crudes, with the aim of finding strains that can reduce their viscosity and extend their use to heavy oils.

If all goes well, when can we expect bacteria to start increasing the flow of oil? Scientists are working to produce bacterial cultures with the right combinations of properties for MEOR but this work is still in its infancy. It is not yet possible to say precisely when it will have been developed into a useful technology.

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What one can do is attempt to assess the relative difficudties of the various proposed techniques, the easiest of which is to inject cultures into reservoirs and feed them from the surface with molasses or other material. Scientists have had experience of this technique but they have not yet worked out how oil is released by bacteria. The concept of growing anaerobic bacteria on crude oil is at an even earlier stage, although scientists have proved that it is possible. As yet there is no guarantee that such bacteria will be able to mobilise oil.

Scientists do not expect to be able to isolate from Nature bacteria which combine all these properties. An attractive approach to the problem is to use genetic manipulation to combine useful properties into a single strain.

We prefer the idea of starting with an organism that can tolerate high reservoir temperatures and pressures, and perhaps has other useful characteristics, and to use genetic engineering techniques to introduce other attributes. So, we are searching for a plasmid that can replicate in the thermophile, and into which DNA can be introduced from other species. As a start to this work, Rick Lilley at QMC is studying a plasmid in a thermophilic organism with the ultimate aim of using it for genetic engineering.

Clearly, there are considerable problems to be overcome. But if the scientists can make reasonable progress, bacteria could ease our oil crisis in the future, perhaps not before the end of the century, but increasingly in the decades to come.

(New Scientist, 94, 1305(May 13, 1982) pp. 408-410)